Hydrogen, the “missing link” to the Energy Transition:
Benchmark & Techno-economic studies of some innovative hydrogen technologies

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Context of the Master Project

- H₂ represents one of the keys of the energy transition and a massive energy carrier to manage the fluctuating nature of renewable sources.
- Hydrogen: Major lever of decarbonization:
  - Key enabler for the renewable energy system
  - Feedstock for Industry
  - Building Heat & Power
  - Transportation sector
- Besides conventional hydrogen production methods by steam methane reforming and low temperature electrolysis, a multitude of solutions are in R&D and pre-industrialization phase. Beyond production technologies, new solutions for storage, transport and use of hydrogen appear on the market.
- Study of some innovative hydrogen technologies.

Objectives

- Identify disruptive technologies & emerging uses of H₂ to understand what is developing from a technological point of view.
- Integrate identified technologies into concrete case studies in order to assess their relevance according to identified uses and markets.

Hydrogen generalities

- How its energy can be recovered?
  - Gas with very high specific energy content (3x more than Diesel)
  - Very low density (15x lower than air)
  - 1 kg H₂ = 11 m³

- How H₂ is produced?
  - Production worldwide: 60 MtH₂/year
  - Fossil source (96%) - Electrolysis (4%)

- Where H₂ is mostly used today?
  - Ammonia production (56%)
  - Refining industry (40%)

Benchmark of innovative H₂ technologies

- H₂ Production technologies
  - Steam Methane Reforming
  - Electrolysis
  - Natural H₂
  - Biomass & waste Gasification

- H₂ Storage technologies
  - Compression & Liquefaction
  - Solid H₂ storage
  - LOHC

- H₂ Application technologies
  - Power-to-Chemicals: Methanol
  - Power-to-Chemicals: Ammonia
  - Electricity generation using FC
  - Power-to-Gas: Methanation

Case studies selection

- Storage and transport of H₂: real challenge
  - H₂ enable of ENR + help decarbonize building heat & power
  - H₂ decarbonize Transportation sector + real project Tractebel

CS 1: Techno-economic evaluation of selected H₂ storage technologies for transportation

Objective: Compare technically & economically two technologies for H₂ transportation: Compressed Gaseous Hydrogen (CGH₂) & Liquid Organic H₂ Carrier (LOHC)

Architecture:
- Quantity of H₂ to transport: 1000 kg/day
- Distance Site A → Site B: 400 km

Results:
- Scenario 1: CGH₂
  - LCOE [€/kg]: 5
  - CAPEX [€]: 4.5 M € 16 M
  - OPEREX [€/year]: 1.4 M € 2.3 M
  - Volume container: 1000 kg
  - B₀ over 24h [m³]: 92 (45%)
  - Transport Costs [€/year]: 230 k€ 55 k€

- Scenario 2: LOHC
  - LCOE [€/kg]: 5

Conclusion:
- Focus on the process of technologies and use of real suppliers data.
- Costs: LOHC technology still expensive vs CGH₂ but mature & available on the market.
- Logistics: LOHC logistics have significant advantages in operational handling vs CGH₂
- Dibenzyltoluene is a heat transfer oil & non explosive. reducing safety & precaution requirements significantly.
- Improvements & developments: 1. Dehydrogenation unit ↔ endo-thermic reactions ↔ energy consuming.
  2. Low capacity of units ↔ high number of units. Lower CAPEX are expected for higher capacities.

CS 2: Techno-economic study of coupling H₂ & PV while using a reversible Solid Oxide Fuel Cell to make energy self-sufficient residential buildings

Objective: Investigate the opportunity of coupling PV & H₂ to make 100% energy self-sufficient buildings. A reversible Solid Oxide Fuel Cell (RSOC) is at the heart of the project as an electrolyzer to generate H₂ through excess electricity from PV system & as a FC to cover the energy consumption of the building.

Architecture:
- Building location: Nice
- Building characteristics: 5 floors; h=20m; 1=20m; w=20m; A=2000m²
- Energy systems: PV (A=450m²) coupled to buffer Li-Ion battery & RSOC for electrical demand. Heat Pump used as the heating system.

PV production vs building consumption

Operating modes of the system:
- Winter mode (from October to March)
- Summer mode (from April to September)

Results:
- Comparison with diesel generator & only batteries

CS 3: Technical pre-feasibility study of H₂ powered ferries and associated refuelling infrastructures

Objective: Determine the viability of developing new island wind power for the purpose of producing H₂. Replace existing fossil-fuelled vessels by new class of hydrogen-powered ferry. Provide high level technical information on Onboard hydrogen storage & usage and on Land-side installations.

Vessel feasibility
- Determine physical sizes of equipment to be installed onboard
- Volume of space & weight required for storage tanks, fuel cell and equipment. Comparison with existing Marine Gas Oil (MGO) system & engine rooms.

Landside feasibility
- H₂ supply chain from production to dispensing & infrastructure footprint analysis.
- 2 models created: upper and lower bounds of plant footprint at ports

Conclusion:
- Determine which island and ferry route demonstrate the greatest viability for the deployment of a H₂ fueled vessel.
- Criteria on both vessel design & necessary land-based infrastructure required for H₂ production.
- Shorthining of 2 routes

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